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Exploring the complex interplay: Correlation between pronated foot and pelvic inclination, femoral anteversion, quadriceps angle, tibial torsion and talus head position in asymptomatic adults

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ABSTRACT

Background: Pronated foot potentially induces alterations in lower limb kinetics, influencing gait patterns and elevating energy expenditure. Nevertheless, a comprehensive understanding of the connection between pronated foot and other static alignment factors remains lacking. Therefore, this study aimed to establish correlations between pronated foot and pelvic inclination, femoral anteversion, Q-angle, tibial torsion, and talus head position. *Method:* This observational study involved 100 individuals of all genders, aged 18-30, with a Foot Posture Index (FPI) score of +6 or higher. Outcome measure evaluations were performed for pelvic inclination, femoral anteversion, Q-angle, tibial torsion, and talus head position. SPSS 25.0 software was used to analyze the correlation between the FPI score and all variables, employing Pearson's correlation and one-way ANOVA followed by post hoc Tukey tests. *Results:* FPI exhibited a significant positive correlation with the Q-angle ($r=0.267$, $p=0.007$), while correlations with other variables were nonsignificant. Strong positive correlations were observed between tibial torsion and talus head position ($r=0.696$, $p=0.000$). Notable differences were identified between FPI scores of 6-8 and 9-10/11-12 across these variables using one-way ANOVA. A regression model utilizing Q-angle as a predictor revealed a statistically significant relationship with FPI ($R=0.267$, $p<0.05$). *Conclusion*: The study revealed significant connection between FPI and Q-angle, indicating possible link between foot posture and lower limb alignment. However, while certain alignment factors showed significant differences across FPI score groups, others didn't exhibit

notable variations, indicating a complex relationship between foot posture and these alignment measures.

Keywords: FPI, pelvic inclination, femoral anteversion, tibial torsion, Q-angle, talus head position

1. INTRODUCTION

The architecture and dynamic functionality of foot arches play a pivotal role in critical foot functions, including shock absorption, weight distribution, and serving as a lever for forward propulsion during locomotion (Aenumulapalli et al., 2017; Stearne et al., 2016). The flat or pronated foot presents with a diminished capacity to absorb impact while walking. This condition encompasses a spectrum of deformities, including medial arch collapse, hindfoot valgus, and forefoot abduction and supination, which can vary in severity. Pronated foot can occur as either primary or, less commonly, secondary, and is frequently seen in children and adults. While often asymptomatic, it can occasionally lead to pain or muscle contractions, prompting patients to seek specialist consultation. Diagnosis of pronated foot relies on clinical assessment. The definitive mechanisms underlying primary pronated foot remain unclear. In children, primary pronated foot may coincide with rotational abnormalities in the lower limbs.

However, in adults, primary pronated foot seems to manifest as an isolated condition, although this assertion lacks definitive confirmation (Cebulski-Delebarre et al., 2016). Adult flatfoot persists or develops after skeletal maturity and is characterized by partial or complete loss (collapse) of the medial longitudinal arch. Almost 20% of the adult population has pes valgus. The prevalence of flatfoot for 5- to 13-year-old children is 28%, with a decreasing trend with age (Chen et al., 2009; Ezema et al., 2014). Pronated foot appears in children, but persists in only 3% of the adults (Sonia et al., 2015; Zafiropoulos et al., 2009). The study reveals a notable gender-based discrepancy in the prevalence of flatfoot among children, with boys exhibiting a significantly higher frequency compared to girls (chi-square = 26.3; $p < 0.001$). The occurrence of flatfoot stands at 35% among boys and 20% among girls.

Moreover, a statistically significant variance in flatfoot prevalence is observed among normal-weight (27%), overweight (31%), and obese (56%) children (chi-square = 18.0; $p < 0.001$). Notably, the influence of obesity demonstrates the significance of $p< 0.01$ across most foot dimensions. However, in terms of flatfoot impact, significance ($p< 0.05$) is only observed concerning foot height for both genders (Chen et al., 2009). Additionally, the study highlights the prevalence of adult-acquired flatfoot deformity (AAFD), estimated to range between 3% to 10%, indicating its common occurrence in the adult population (Pasapula et al., 2018). A pronated foot alters the mechanics of the human body due to foot pronation and a flattened arch. Hyper-pronation impacts the normal intersegmental relationship, with pronation leading to internal rotation of the thigh and anterior pelvic tilt.

It has been suggested that biomechanical alterations resulting from abnormal alignment may contribute to neuromuscular issues. Nevertheless, there remains inadequate comprehension regarding the connection between anatomical alignment and the risk of injury (Khamis and Yizhar, 2007; AlKhouli et al., 2017; Tateuchi et al., 2011). The investigation into alignment factors within the lower body kinetic chain has been a focal point in various studies Khamis and Yizhar, (2007), Nguyen et al., (2009), Nguyen and Schultz, (2009) but has often revolved around limited factors. However, the potential interconnectedness of these alignment faults necessitates a more comprehensive examination to solely capture the static position of the lower extremity (Khamis and Yizhar, 2007; Nguyen et al., 2009; Nguyen and Shultz, 2009).

While research efforts by Nguyen et al., (2009) and Khamis and Yizhar, (2007) have attempted to correlate specific components of alignment factors, there's a noticeable gap in understanding how foot pronation influences the kinetic chain of the lower extremity. In essence, while past research has contributed valuable insights into isolated aspects of alignment factors, the interconnected nature of these factors and their relationship with foot pronation necessitate a more comprehensive examination to better understand the static position of the lower extremity within the kinetic chain.

2. METHODOLOGY

A cohort of 100 individuals, comprising both male and female students, patient attendants, attending the Department of Physiotherapy at SV NIRTAR, Bairoi, Cuttack, Orissa, was selected for this study between year 2019 to 2020. Inclusion criteria encompassed asymptomatic individuals aged 18-30 years, exhibiting pronated foot on observation, without complaints of pain or stiffness at the knee or ankle, and no history of knee injury. Furthermore, participants with a history of Grade 1 and/or 2 ankle sprain (occurring at least 3

months prior) and a Foot Posture Index (FPI) score of +6 or higher Gandhi and Salvi, (2017) were enrolled. Exclusion criteria involved a history of pathological conditions at the spine or lower limb joints, traumatic conditions at the spine, hip, or knee (including fractures, surgery, and ligament injuries), and individuals with a history of Grade 3 ankle sprain or Grade 1/2 ankle sprain <3 month.

The written consent were obtained from the participants who met the inclusion criteria. The assessment included the following measures: FPI, Pelvic Inclination, Femoral Anteversion, Q-angle, Tibial Torsion, and Talus head position. A transparent goniometer, handheld pelvic inclinometer, and a plinth were use for the measurements. Subject variables was analyze once, maintaining a single measurement session for each participant.

The Foot Posture Index

The Foot Posture Index involves the evaluation of six clinical criteria to assess the foot: a) Talus head position, b) Curvatures of the supra and infra lateral malleoli, c) Position of the calcaneus in the frontal plane, d) Presence of prominence around the Talonavicular joint, e) Consistency of the medial longitudinal arch, and f) Forefoot abduction/adduction concerning the rearfoot. All assessments were perform with subjects in a relaxed, double-limb support position during a static stance.

Q angle measurement

The subject stood in a relaxed, double-limb support stance with even weight distribution. Using a goniometer, we measured the angle formed between a line connecting the Anterior Superior Iliac Spine (ASIS) and the midpoint of the patella, and another line connecting the midpoint of the patella to the tibial tuberosity, extending above the knee (Figure 1).

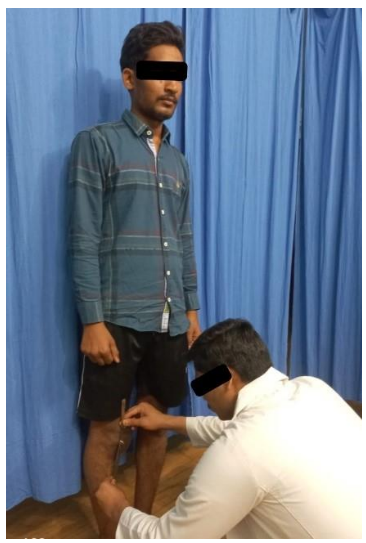

Figure 1 Measuring Q-angle

Measurement of femoral anteversion

The individuals lie in a face down position, with their knees bent at a 90° angle at the table's edge. The examiner palpates the back of the greater trochanter of the femur and proceeded to passively rotate the hip both inward and outward until the greater trochanter aligned parallel to the examining table or reached its farthest lateral position. Using a goniometer, the extent of anteversion was measured by determining the angle between the vertical line and a line drawn through the tibia's shaft, intersecting the midpoint between the medial and lateral condyles (Gandhi and Salvi, 2017) (Figure 2).

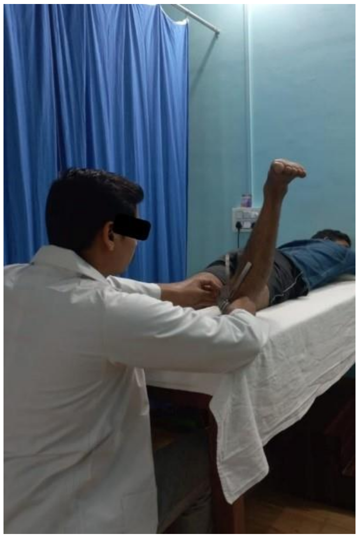

Figure 2 Measuring femoral Anteversion

Measurement of pelvic inclination

Using a handheld pelvic inclinometer, the subject stood in a relax, double-limb support stance. One end of the caliper was place on the Posterior Superior Iliac Spine (PSIS), while the other end on the Anterior Superior Iliac Spine (ASIS). The closed ends of the caliper were then adjusted until the pendulum freely hung over the protractor. This positioning ensures the protractor's plane is perpendicular to the floor, for the measurement of the ilium's tilt angle from the protractor scale (Gajdosik et al., 1985) (Figure 3).

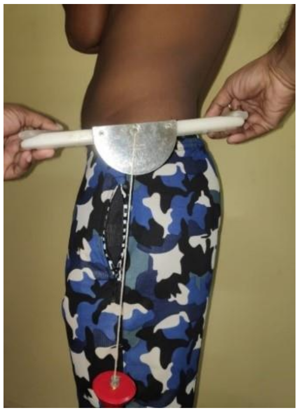

Figure 3 Measuring pelvic inclination

Measurement of tibial torsion

The subject lying prone, knees flexed at 90 degrees, and ankles in a neutral position. The trans-malleolar axis is determined by marking the center points of each malleolus and drawing a line connecting these marks along the heel's plantar aspect. Subsequently, the measurement for tibial torsion angle obtained between a line perpendicular to the trans-malleolar axis and the thigh's long axis (Figure 4).

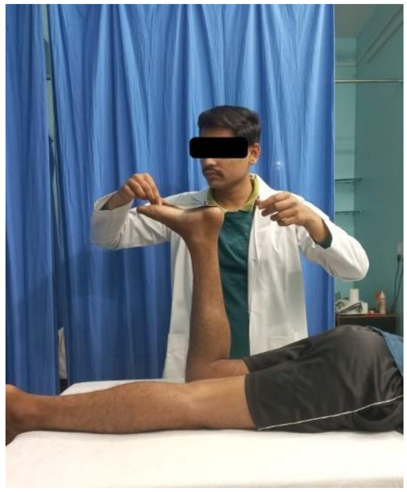

Figure 4 Measuring tibial torsion

3. RESULTS

Data analysis was done using SPSS version 25.0. Multivariate analysis using a linear regression model was done for FPI with all the variables, and Bivariate correlation (Pearson) of all variables was also done to see their relationship with FPI. Based on FPI scoring three groups were made group I (score 6-8), group II (score 9-10), group III (score 11-12), and One way ANOVA post hoc (tukey) test was done to see the difference between the group in talus position, tibial torsion, femoral torsion, Q angle and pelvic inclination. The statistical level of significance was set at 0.05.

There were 54 female feet and 46 male feet in the study, 72 feet in group 1 (FPI 6-8), 18 in group 2(FPI 9-10) and, 10 in group 3(FPI 10-11). The bivariate correlation results suggest that there is a significant positive correlation between FPI and Q Angle ($r = 0.267$, $p = 0.007$), while the relationships between FPI and Tibial Torsion ($r = 0.111$, $p = 0.274$), Femoral Torsion ($r = 0.165$, $p = 0.101$), and Pelvic Inclination ($r = -0.157$, $p = 0.119$) are not statistically significant (Table 1). Strong positive correlations were found between Tibial Torsion and talus head position ($r = 0.696$, $p = 0.000$). The correlation is statistically significant at the 0.01 level (1-tailed), indicating a robust relationship between the two variables (Table 2).

Table 1 Pearson correlation coefficients and their corresponding two-tailed p-values for the correlation between Foot Posture Index (FPI) and Tibial Torsion, Q angle, Femoral Torsion, and Pelvic Inclination.

Foot posture Index (FPI) and Tibial Torsion		
	FPI	Tibial Torsion
FPI	1.00	r = 0.111 (p = 0.274)
Tibial Torsion	r = 0.111 (p = 0.274)	1.00
FPI and Q angle		
	FPI	Q Angle
FPI	1.00	r = 0.267** (p = 0.007)
Q angle	r = 0.267** (p = 0.007)	1.00
FPI and Femoral torsion		
	FPI	Femoral Torsion
FPI	1.00	r = 0.165 (p = 0.101)
Femoral Torsion	r = 0.165 (p = 0.101)	1.00
FPI and Pelvic Inclination		
	FPI	Pelvic Inclination
FPI	1.00	r = -0.157 (p = 0.119)

Pelvic Inclination	r = -0.157 (p = 0.119)	1.00

Table 2 Pearson correlation coefficients and their corresponding p-values for the correlation between Tibial Torsion and talus head position.

Tibial torsion and talus head position		
	Tibial torsion	Talus head position
Tibial torsion	1.00	r = 0.696 (p = 0.000)
Talus head position	r = 0.696 (p = 0.000)	1.00

A One-Way ANOVA was conducted to analyze the impact of FPI group scores on different variables.

FPI group scores on Talus head position, post hoc Tukey tests revealed significant mean differences between FPI Score 6-8 vs. 11-12 (-0.600, p = 0.005), while FPI score 6-8 vs. 9-10 (-0.400, p = 0.069) and FPI score 9-10 vs. 11-12 (0.200, p = 0.486) were not statistically significant (Table 3).

FPI group scores on Tibial Torsion, post hoc Tukey tests revealed significant mean differences between FPI Score 6-8 vs. 9-10 (-3.100, p = 0.001) and FPI Score 6-8 vs. 11-12 (-4.300, p = 0.000), while FPI score 9-10 vs. 11-12 (1.200, p = 0.273) were not statistically significant (Table 3).

FPI group scores on Q Angle, post hoc Tukey tests revealed significant mean differences between FPI Score 6-8 vs. 9-10 (-1.600, p = 0.015) and FPI Score 6-8 vs. 11-12 (-2.800, p = 0.000), while FPI score 9-10 vs. 11-12 (1.200, p = 0.078) were not statistically significant (Table 3).

FPI group scores on Femoral Torsion, post hoc Tukey tests revealed a significant mean difference between FPI Score 6-8 vs. 9-10 (-1.300, p = 0.036), while FPI score 6-8 vs. 11-12 (-1.100, p = 0.084) and FPI score 9-10 vs. 11-12 (0.200, p = 0.914) were not statistically significant (Table 3).

Table 3 One-way ANOVA (Post hoc Tukey) to analyze the impact of FPI group score on Tibial Torsion, Q angle, Femoral Torsion, and talus head position.

Foot Posture Index (FPI)	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Talus head position					
FPI Score 6-8 vs. 9-10	-0.400	0.172	0.069	-0.83	-0.03
FPI Score 6-8 vs. 11-12	-0.600	0.172	0.005	-1.03	-0.17
FPI Score 9-10 vs. 11-12	0.200	0.172	0.486	-0.23	0.63
Tibial Torsion					
FPI Score 6-8 vs. 9-10	-3.100	0.761	0.001	-4.99	-1.21
FPI Score 6-8 vs. 11-12	-4.300	0.761	0.000	-6.19	-2.41
FPI Score 9-10 vs. 11-12	1.200	0.761	0.273	-0.69	3.09
Q angle					
FPI Score 6-8 vs. 9-10	-1.600	0.530	0.015	-2.991	-0.29
FPI Score 6-8 vs. 11-12	-2.800	0.530	0.000	-4.11	-1.49
FPI Score 9-10 vs. 11-12	1.200	0.530	0.078	-0.51	2.51
Femoral torsion					
FPI Score 6-8 vs. 9-10	-1.300	0.494	0.036	-2.52	-0.08
FPI Score 6-8 vs. 11-12	-1.100	0.494	0.084	-2.32	0.12
FPI Score 9-10 vs. 11-12	0.200	0.494	0.914	-0.91	1.42

Multiple comparisons were conducted to assess the differences in Pelvic tilt among different groups based on FPI scores. The Tukey HSD test was employed for post hoc analysis. Significant mean differences were found between FPI Score 6-8 vs. 9-10 (-1.700, p = 0.124) and FPI Score 6-8 vs. 11-12 (-1.000, p = 0.467), while the comparison between FPI Score 9-10 vs. 11-12 was not statistically significant (0.700, p = 0.684) (Table 4).

Table 4 Multiple Comparison Tukey HSD (post hoc analysis) to analyze the impact of FPI group score on pelvic tilt.

FPI	Mean Difference	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Pelvic tilt					
FPI Score 6-8 vs. 9-10	-1.700	0.837	0.124	-3.78	0.38
FPI Score 6-8 vs. 11-12	-1.000	0.837	0.467	-3.08	1.08
FPI Score 9-10 vs. 11-12	0.700	0.837	0.684	-1.38	2.7

The regression analysis indicates that the model, with Q Angle as a predictor, explains a statistically significant amount of variance in the FPI ($R = 0.267$, $p < 0.05$). An adjusted R-squared of 0.071 suggests that approximately 7.1% of the variance in the dependent variable is explained by the model. Approximately 7.1% of the variability in FPI is accounted for by Q Angle (Table 5).

Table 5 Regression analysis results for the relationship between Q Angle and Foot Posture Index.

Variable	R	R2	Adjusted R2	Std. error of estimate
Constant: Q Angle Dependent: FPI	0.267	0.071	0.062	1.790

4. DISCUSSION

The study conducted various analyses to explore the relationships between FPI (FPI), lower limb alignments (Tibial Torsion, Q angle, Femoral Torsion, Pelvic Inclination), and talus head position. This study's findings resonate with the research conducted by Khamis and Yizhar, (2007), emphasizing the influence of pronation on lower limb alignments and its effects throughout the kinetic chain. They observed an increase in compensation along the proximal kinetic chain as foot pronation increased with varying degrees of wedge inclination (Khamis and Yizhar, 2007). Similarly, the present study revealed significant increases in tibial torsion and Q angle with escalating FPI scores from Groups 1 to 2 and Groups 1 to 3. However, we did not observe significant changes in variables between Groups 2 and 3. The lack of significant difference from groups 2 to 3 may be attributed to the incremental difference in FPI scoring for moderate and hyper-pronated foot not being equivalent to 5o, resulting in minimal or non-significant alterations in tibial torsion and Q angle (Khamis and Yizhar, 2007).

Furthermore, while Khamis and Yizhar, (2007) suggested that an inclination wedge of 100 could result in internal femoral torsion, our study cohort comprised young adults, potentially lacking substantial degrees of pronation and torsional deformities often linked with acquired pronated feet (Khamis and Yizhar, 2007). Factors like being overweight, secondary to genu valgum, footwear choices, and ethnicity, as mentioned by Hernandez et al., (2007), could contribute to acquired pronated feet without significant torsions in the lower limb. The absence of considerable femoral torsion and pelvic inclination in our subjects might explain the lack of correlation observed in our multiple regression analysis when considering all subjects without categorizing them according to FPI scores.

Pronated foot and tibial torsion

The insights from Boerum and Sangeorzan, (2003) elaborate on the implications of acquired pronated foot in adults, highlighting increased tension in the triceps surae and subsequent development of tightness in the hamstring muscles. This tightness in the hamstrings regulates tibial torsion (Boerum and Sangeorzan, 2003). Additionally, findings from suggest that futsal players with hamstring tightness tend to exhibit increased external torsion of the tibia compared to those without such tightness (Minoonejad et al.,

2016). Both these perspectives substantiate our study results, indicating an increase in tibial torsion aligned with the degree of the pronated foot according to FPI scores (Levangie and Norkin, 2005).

Pronated foot and Q angle

As outlined by Khamis and Yizhar, (2007), foot pronation leads to a medial rotation of the tibia and femur. Additionally, increased femoral torsion results in a greater medial shift of the patella. Conversely, external torsion of the tibia causes the tibial tuberosity to move farther from the patella, consequently leading to an increase in the Q angle (Khamis and Yizhar, 2007). However, this study did not indicate an increase in femoral torsion. Therefore, the observed elevation in the Q angle in our findings ($r = 0.267$, $p = 0.007$) might be attributed to the heightened tibial torsion instead.

Pronated foot effect on femoral torsion and Pelvic inclination

In the current study, we found that there is no statistical relationship between femoral torsion and pelvic inclination with the pronated foot. In their study on knee osteoarthritis and hind foot deformity, suggested that to reflect changes in the kinetic chain on the proximal side, there must be a failure of compensation by the lower joints or are unable to compensate the alignment then only the other joints in the kinetic chain will try to accommodate the changes. In this study, we found that compensation had occurred by an increase in tibial torsion and Q angle, which could be the reason that no significant change occurred in femoral torsion and pelvic inclination. The other important cause of no relationship could be that all the measurements were taken in static posture which requires very little compensation about when one is mobile (Gandhi and Salvi, 2017).

Talus position and tibial torsion

The correlation between talus head position and tibial external torsion stems from pronated foot mechanics. In a pronated foot, the talus tends to adduct, causing internal rotation of the tibia. However, during midstance, the foot needs to undergo supination to propel the body forward efficiently. This inadequate supination during midstance leads to compensatory external tibial rotation, potentially causing external torsion in the tibia (Levangie and Norkin, 2005; Meehan and Brage, 2003). Compensatory strategies within the body adapt to alterations in specific lower extremity joints. The study observed a predominant presence of subjects within the 6-8 FPI score range, coupled with their youthfulness, potentially contributing to the lack of significance in correlations when employing a linear regression model without categorizing based on scores. Variations in individual bony alignments, anatomic structures, and soft tissue integrity, not addressed in this study, significantly influence lower limb alignment.

Furthermore, this research did not account for interdependent factors such as genu recurvatum, patella position, and core strength, which play roles in static alignment (Gandhi and Salvi, 2017; Levangie and Norkin, 2005; Schamberger et al., 2002). Craig's test, though commonly employed, exhibits limited reliability (inter-rater ICC = 0.85) for measuring femoral anteversion. Furthermore, it does not utilize a weight-bearing position, resulting in imprecise outcomes. Regrettably, the literature lacks valid clinical methods for accurately measuring femoral torsion. Similarly, there is no validated test available for assessing tibial torsion in a weight-bearing position, compromising its effectiveness in evaluating lower limb alignment without incorporating functional weight-bearing positions (Gandhi and Salvi, 2017).

Unlike Gandhi and Salvi, (2017), which found no correlation between pronated feet and lower extremity alignment, our findings showed significant differences in tibial torsion and Q angle based on the severity of pronation as categorized by FPI Scores grouping. They combined subjects with varying degrees of foot pronation without considering potential differences in compensation mechanisms across different levels of pronation severity, possibly leading to their inability to observe a significant relationship between foot pronation severity and associated factors (Gandhi and Salvi, 2017). The outcomes of this study align with Khamis and Yizhar, (2007) research, particularly about tibial torsion and Q angle. However, we encountered discrepancies in femoral torsion and pelvic inclination measurements.

While we assessed femoral torsion in a lying position, Khamis and Yizhar, (2007) observed alignments in a standing position using a three-dimensional motion analysis system (VICON), which was not feasible in our study due to cost constraints. A prospective avenue for research involves examining the correlation between symptomatic pronated foot subjects and comparing them with asymptomatic pronated foot individuals or those with a regular foot posture (FPI less than 6). This comparison may offer deeper insights into alignment variations among those without pronated feet. Additionally, future studies could leverage CT scans or utilize

3D movement analysis laboratories to obtain precise measurements of alignments. These methods could provide accurate data for various alignment assessments. Furthermore, delving into EMG studies offers a promising avenue for examining potential differences in lower limb muscle activity between pronated and regular foot postures.

5. CONCLUSION

In conclusion, this study identified significant associations between FPI and Q Angle, Tibial Torsion, and Talus head position. However, it found no substantial correlations between FPI and Femoral Torsion or Pelvic Inclination. Nevertheless, it is essential to consider that the positioning of adjacent proximal and distal joints can influence the alignment of one joint. Therefore, therapists should recognize the importance of assessing the foot's role when evaluating conditions related to the back, hip, or knee. These observations highlight the intricate interplay between foot pronation, lower limb alignments, and kinetic chain compensation, underscoring the multifactorial nature of foot posture and its implications on the entire lower limb biomechanics. Further investigations considering various factors influencing foot posture and torsions are warranted to comprehensively understand their cumulative impact on lower limb alignments and kinematics.

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We thank the participants who were all contributed samples to the study.

Author Contributions

All authors contributed in conception, designing, writing and reviewing the manuscript.

Ethical approval

The study was approved by the SVNIRTAR Institutional Ethical Committee (Ethical approval code: DPT 9A 11(2018)).

Informed Consent

Written & Oral informed consent was obtained from all individual participants included in the study.

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Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

REFERENCES

1. Aenumulapalli A, Kulkarni MM, Gandotra AR. Prevalence of Flexible Flat Foot in Adults: A Cross-sectional Study. J Clin Diagn Res 2017; 11(6):AC17-AC20. doi: 10.7860/JCDR/2017/26566.10059 N
2. AlKhouli M, Ghait AS, Abogazya AA. Relationship Between Flatfoot and Q Angle in Male Secondary School Students. Int J Physiother Res 2017; 5(6):2477–81. doi: 10.16965/ijpr.2017.232
3. Boerum DV, Sangeorzan BJ. Biomechanics and pathophysiology of flat foot. Foot Ankle Clin 2003; 8(3):419-30. doi: 10.1016/s1083-7515(03)00084-6
4. Cebulski-Delebarre A, Boutry N, Szymanski C, Maynou C, Lefebvre G, Amzallag-Bellenger E, Cotten A. Correlation between primary flat foot and lower extremity rotational misalignment in adults. Diagn Interv Imaging 2016; 97(11):1151–1157. doi: 10.1016/j.diii.2016.01.011
5. Chen JP, Chung MJ, Wang MJ. Flatfoot Prevalence and Foot Dimensions of 5– to 13-Year-Old Children in Taiwan. Foot Ankle Int 2009; 30(4):326-32. doi: 10.3113/FAI.2009.0326

6. Ezema C, Abaraogu U, Okafor G. Flat foot and associated factors among primary school children: A cross-sectional study. Hong Kong Physiother J 2014; 32(1):13–20.
7. Gajdosik R, Simpson R, Smith R, DonTigny RL. Pelvic tilt: Intratester reliability of measuring the standing position and range of motion. Phys Ther 1985; 65(2):169-74. doi: 10.1093/ptj/65.2.169
8. Gandhi N, Salvi R. Correlation between Pronated Foot and Pelvic Inclination, Femoral Anteversion, Quadriceps Angle and Tibial Torsion. Int J Physiother 2017; 4(4):229–235. doi: 10.15621/ijphy/2017/v4i4/154718
9. Hernandez AJ, Kimura LK, Laraya MHF, Fávaro E. Calculation of Staheli's plantar arch index and prevalence of flat feet: a study with 100 children aged 5–9 years. Acta Ortop Bras 2007; 15:68–71.
10. Khamis S, Yizhar Z. Effect of feet hyperpronation on pelvic alignment in a standing position. Gait Posture 2007; 25(1):127-34. doi: 10.1016/j.gaitpost.2006.02.005
11. Levangie PK, Norkin CC. Joint structure and function: a comprehensive analysis. 4th ed. Philadelphia, PA: F.A. Davis Co., 2005; 588.
12. Meehan RE, Brage M. Adult acquired flat foot deformity: clinical and radiographic examination. Foot Ankle Clin 2003; 8(3):431-52. doi: 10.1016/s1083-7515(03)00019-6
13. Minoonejad H, Tasoujian E, Amiri H, Manteghi R. Research Paper: Comparison of Q Angle and Tibial Torsion Among Premier League Futsal Players with & without Hamstring Tightness. Physical Treat 2016; 6(1):51-58. doi: 10.18869/NRIP.PTJ.6.1.51
14. Nguyen AD, Boling MC, Levine B, Shultz SJ. Relationships Between Lower Extremity Alignment and the Quadriceps Angle. Clinical Journal of Sport Medicine. Clin J Sport Med 2009; 19(3):201-6. doi: 10.1097/JSM.0b013e3181a38fb1
15. Nguyen AD, Shultz SJ. Identifying Relationships Among Lower Extremity Alignment Characteristics. J Athl Train 2009; 44(5):511-8. doi: 10.4085/1062-6050-44.5.511
16. Pasapula C, Shariff S, Cutts S, West J, Kobezda T. Adult Acquired Flat Foot: A New Biomechanical Classification for the Deformity Based on two Point Failure of the Medial Column. Clin Res Foot Ankle 2018; 6:270. doi: 10.4172/2329-910X.1000270
17. Schamberger W, Samorodin FT, Webster C. The malalignment syndrome: implications for medicine and sport. Churchill Livingstone, 2002; 450.
18. Sonia J, Nadia L, Manel A, Samia F, Mohamed B, Walid O, Afif Z, Faycel K. Children Flat Foot and Lower Limb Rotational Profile: A Cross-Sectional Descriptive Study. Open J Orthop 2015; 5:326-335. doi: 10.4236/ojo.2015.510044
19. Stearne SM, McDonald KA, Alderson JA, North I, Oxnard CE, Rubenson J. The Foot's Arch and the Energetics of Human Locomotion. Sci Rep 2016; 6:19403. doi: 10.1038/srep19403
20. Tateuchi H, Wada O, Ichihashi N. Effects of calcaneal eversion on three-dimensional kinematics of the hip, pelvis and thorax in unilateral weight bearing. Hum Mov Sci 2011; 30(3):566-73. doi: 10.1016/j.humov.2010.11.011
21. Zafiropoulos G, Prasad KS, Kouboura T, Danis G. Flat foot and femoral anteversion in children--a prospective study. Foot (Edinb) 2009; 19(1):50-4. doi: 10.1016/j.foot.2008.09.003